UNCERTAINTY REDUCTION, CONDITIONED REINFORCEMENT, AND OBSERVING

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In a concurrent-chains procedure, pigeons chose between equivalent mixed and multiple fixed-interval schedules of reinforcement. In the first experiment, preference for the multiple schedule was higher when the probability of the shorter fixed interval was less than .50 than for complementary points, an outcome consistent with the delay-reduction hypothesis of conditioned reinforcement and observing, but inconsistent with the uncertainty-reduction hypothesis which requires symmetrical preferences with a maximum when the two intervals are equiprobable. A second experiment assessed preference for equivalent mixed and multiple schedules when each choice outcome resulted in two reinforcements, one on the longer and one on the shorter fixed interval. The order of the two fixed intervals was determined probabilistically. Pigeons again preferred multiple to mixed schedules, although multiple-schedule preference did not vary systematically with the likelihood of the shorter fixed interval occurring first. The results from these choice procedures are consistent with those from the observing-response literature in suggesting that the strength of a stimulus cannot be well described as a function of the degree of uncertainty reduction the stimulus provides about reinforcement.

Key words: conditioned reinforcement, uncertainty reduction, choice, delay-reduction hypothesis, concurrent-chains schedule, mixed schedule, multiple schedule, key peck, pigeons

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The uncertainty-reduction hypothesis of conditioned reinforcement states that the strength of a stimulus is a function of the degree of uncertainty reduction the stimulus provides about reinforcement. This hypothesis, in varying forms, has been supported by Berlyne (1957, 1960), Bloomfield (1972), Hendry (1969a), and Schaub and Honig (1967), among others (see Fantino, 1977, for a review). The uncertainty-reduction hypothesis has been most commonly applied to studies of observing responses. For example, in Wyckoff's (1952) observing response procedure, periods during which key pecking was reinforced on a fixed-interval (FI) schedule alternated with periods of extinction. When the pigeon pressed a treadle, it produced a key color that was correlated with the schedule in effect, e.g., red with FI and green with extinction, in one condition but uncorre-

lated with the schedule in effect in a second condition. More pedal presses—or "observing responses"—occurred when the colors were correlated with the schedules in effect (multiple schedule) than when they were uncorrelated (mixed schedule). While this general result, replicated in a large number of studies (cf. Fantino), is consistent with the uncertainty-reduction hypothesis, it is also consistent with the delay-reduction hypothesis of conditioned reinforcement which states that only stimuli correlated with a reduction in time to primary reinforcement should maintain observing (Fantino). Whereas the fixed-interval outcome is correlated with a reduction in time to primary reinforcement, the extinction outcome is not.

Two types of evidence have been gathered to evaluate the relative efficacy of the uncertainty-reduction and delay-reduction hypotheses in the observing-response paradigm. One assesses whether or not the stimulus correlated with the lower rate of reinforcement (hereafter the "lower-valued outcome") maintains observing, as required by the uncertainty-reduction hypothesis but not by the delay-reduction hypothesis. Here the results are generally straightforward: lower-valued stim-

uli do not appear to reinforce observing (e.g., Blanchard, 1975; Dinsmoor, Browne, & Lawrence, 1972; Jenkins & Boakes, 1973; Kendall and Gibson, 1965; Mulvaney, Dinsmoor, Jwaideh, & Hughes, 1974; cf. Fantino, 1977). These findings have been extended by Auge (1973, 1974) and by Jwaideh and Mulvaney (1976), who have shown that a stimulus reducing uncertainty may not even be reinforcing when it is correlated with positive reinforcement. Specifically, if two schedules of positive reinforcement are alternated, only the stimulus correlated with the more positive reinforcement schedule will maintain observing. For example, observing is maintained by the stimulus correlated with the lesser of two delays to reinforcement but not by the stimulus correlated with the greater delay (Auge, 1974). Such findings, of course, are not readily compatible with the uncertainty-reduction hypothesis. They are consistent with the delay-reduction hypothesis, however. When the subject does not observe, it remains in the presence of the mixed stimulus, correlated with both short and long delays to reinforcement and therefore with an intermediate average delay. The positive stimulus is correlated with the short delay and therefore a reduction in average time to reinforcement relative to the mixed stimulus. The lower valued stimulus is correlated with the longer delay and therefore an increase in average time to reinforcement relative to the mixed stimulus. Thus, only the positive stimulus should maintain observing.

The second type of study has assessed the effect of varying the probability of the positive outcome on observing. According to information theory, the amount of uncertainty reduction transmitted by a stimulus should be maximal when the higher and lower valued outcomes are equiprobable (Garner, 1962). Hence, rate of observing should approximate a symmetrical function of the probability of the positive outcome, with a peak around $p = .50$. According to the delay-reduction hypothesis, however, the function relating conditioned reinforcement to the probability of the positive outcome should be an asymmetrical one with a peak approaching $p = 0$. This requirement depends on the fact that as p, the probability of the positive outcome, decreases, the frequency of reinforcement in the presence of the mixed schedule stimulus also decreases. Thus, the difference in conditioned-reinforcing strength between the multiple stimulus correlated with the positive outcome and that correlated with the mixed schedule increases as p decreases. Similarly, as p increases, the frequency of reinforcement in the presence of the mixed schedule stimulus also increases and approaches the reinforcement frequency in the presence of the positive multiple stimulus; the difference in conditioned-reinforcing strength between the multiple stimulus correlated with the positive outcome and the stimulus correlated with the mixed schedule thus decreases as p increases. It follows, therefore, that more observing should occur when the positive outcome is unlikely (e.g., $p = .33$) than for the complementary points (e.g., $p = .67$). In general, the subject's observing responses produce more conditioned reinforcement the *lower* p (of course, at $p = 0$, essentially an extinction point, no observing should occur). This argument has been made in more detail by Fantino (1977) and McMillan (1974). Although there is less evidence on this point than on the question of whether or not "bad news" is reinforcing, what evidence there is again favors the delay-reduction hypothesis over the uncertainty-reduction hypothesis (e.g., Fantino, 1977; McMillan, 1974).

Another way of assessing the strength of a stimulus is in a choice situation not involving observing responses. For example, choice between equivalent mixed and multiple schedules may be measured. Again both the uncertainty-reduction and delay-reduction hypotheses require preference for multiple over comparable mixed schedules, an outcome that has been reported frequently (e.g., Bower, McLean & Meacham, 1966; Eckerman, 1973; Green & Rachlin, 1977; Hendry, 1969b; Hursh & Fantino, 1974). Again—and for the same reasons as in the observing-response case—the uncertainty-reduction hypothesis predicts that preference for the multiple schedule should be greatest when the positive and negative outcomes are equiprobable; the delay-reduction hypothesis requires that the preference function peaks where the positive outcome is less than equiprobable. On this point the evidence is ambiguous.

Of the five studies cited above, four are relevant since they varied the probability of the positive outcome (Hursh and Fantino's study did not). Bower et al. (1966) and Hendry (1969b) obtained no systematic effect of this

variation on choice, perhaps because they used concurrent ratio schedules in the choice phase. With concurrent ratios, subjects are apt to distribute most of their choices to the preferred alternative (e.g., Herrnstein, 1958; Herrnstein & Loveland, 1975), thereby potentially obscuring gradations of preference.

Eckerman (1973) obtained asymmetry of preference consistent with the delay-reduction hypothesis. Interpretation of his results is somewhat complicated, however, since he reports order effects and because he used a sequential choice procedure as opposed to concurrent procedures used in other studies. Green and Rachlin (1977), on the other hand, obtained asymmetrical preferences inconsistent with both the uncertainty-reduction and delay-reduction hypotheses. Specifically, their pigeons tended to show greater preferences for the multiple schedule when the positive outcome was more probable (e.g., $p = .90$) than for complementary values (e.g., $p = .10$). Their study was the only one in which the lesser valued outcome was not a schedule of reinforcement providing a relatively low rate of reinforcement. Instead, their negative outcome was a blackout and extinction.

The main purpose of the present experiments was to assess the effects of varying the probability of the positive outcome on preference for multiple vs. mixed schedules in a standard concurrent-chains procedure in which the lower valued outcome was a schedule of reinforcement providing a relatively low rate of reinforcement. The major question to be answered is whether or not choice in a standard concurrent-chains procedure would be similarly affected by the same parametric manipulations that affect the strength of a stimulus in an observing situation.

EXPERIMENT 1

METHOD

Subjects

Four adult male White Carneaux pigeons (B-22, B-20, 2958, and 6242) maintained at approximately 80% of their free-feeding weights served. All pigeons had experienced a variety of experimental procedures, including concurrent-chains schedules.

Apparatus

A standard experimental pigeon chamber was used (Ferster & Skinner, 1957). A solenoid-operated grain hopper centrally located between two circular response keys provided 3-sec access to mixed grain. The two translucent response keys were mounted 7.6 cm apart and 22.8 cm above the floor. Each key was illuminated with either red, green, blue, or white light from stimulus projectors (Industrial Electronic Engineers #1820). Each peck on a lighted key produced auditory feedback by operating a 110-V ac relay. A minimum force of .15 N was required to operate the keys. No houselights were used. White noise masked extraneous noise. Standard electromechanical scheduling equipment was located in an adjacent room.

Procedure

In the concurrent-chains procedure, the pigeon is presented with two concurrently available response keys, each illuminated by a stimulus associated with the initial link of a chain. Occasionally, a peck on a key during the initial link produces the following two changes: (a) the stimulus on the key pecked changes from one associated with the initial link of a chain to one associated with the terminal component of a chain, and (b) the other key becomes dark and inoperative. Pecking on the terminal-link key then yields 3-sec access to mixed grain (reinforcement), according to the terminal-link schedule in effect on that key. Following reinforcement, the initial links are reinstated. The dependent variable is the distribution of initial-link responding: the number of initial-link responses on one key divided by the sum of initial-link responses. The independent variable is generally some difference between the terminal links (in these experiments, the difference between multiple and mixed schedules in the terminal links).

During the initial links, identical variable-interval (VI) 30-sec schedules were in effect. Whenever a terminal link was entered, either an FI 10-sec or an FI 60-sec schedule was in effect. A probability gate, set at some level (p), randomly selected the specific schedule that was in effect. This probability was the same for each terminal link. If a mixed schedule was in effect during a terminal link, the keylight was blue, irrespective of whether the

probability gate selected the FI 10-sec or FI
60-sec schedule. If a multiple schedule was in
effect during a terminal link, the keylight was
red when the probability gate selected the FI
10-sec schedule or green when it selected an
FI 60-sec schedule. Following the food presen-
tation, arranged by the terminal-link schedule,
the initial links were reinstated. When either
VI schedule in the initial link arranged the
opportunity to enter its terminal link, the
other VI schedule became inoperative. This
"forced-choice procedure" (after Stubbs &
Pliskoff, 1969) has the effect of ensuring that
the two terminal links are entered equally
often. Because it constrains the subject occa-
sionally to sample the less preferred alterna-
tive, choice proportions obtained with this
method tend to be lower than those obtained
with independent VIs in the initial links (e.g.,
MacEwen, 1972). With independent VIs, the
subject's choice is unconstained (except, of
course, by the effects of reinforcement). When
one alternative is strongly preferred to an-
other, the obtained rate of reinforcement in
the presence of the less preferred alternative
may be lower than the scheduled rate, thus
further affecting preference. This problem is
avoided with the "forced-choice" procedure.
Because the two procedures produce different
choice proportions, extra care must be taken
in making comparisons across studies using the
different procedures. In the present study, how-
ever, the tests of the uncertainty-reduction and
the delay-reduction hypotheses depended on
comparisons across conditions of the experi-
ment. It was thus deemed desirable to ensure
that comparable rates of reinforcement oc-
curred in all conditions.

The data of primary interest were the choice
proportions between the mixed and multiple
schedules across the various probabilities that
the FI 10-sec schedule would be produced,
given a terminal-link entry. There were 7 prob-
abilities at which behavior was examined: .05,
.15, .35, .50, .65, .85, and .95. Thus, at the .05
probability level, the pigeon produced the FI
10-sec terminal schedule on approximately 5%
of the terminal-link entries; on the remaining
95% of the entries, it produced the FI 60-sec
schedule. In contrast, at the .95 probability
level, the pigeon produced the FI 10-sec sched-
ule on approximately 95% of the terminal-
link entries; on the remaining 5% of the en-
tries, it produced the FI 60-sec schedule.

For a given probability level, the compari-
sons were conducted in the following way.
First, 10 sessions were conducted in which both
the left and right terminal links were corre-
lated with mixed schedules. Then one termi-
nal link was changed to a multiple schedule
while the other schedule remained mixed. The
pigeons were exposed to these terminal links
until their initial-link responding satisfied a
stability criterion. This criterion required that
the pigeons perform in at least 15 sessions. Fol-
lowing the 15th session and any session there-
after, the choice proportions from the last nine
sessions were considered in three blocks of
three sessions each. When the means of the
three blocks differed by no more than .07, and
when the means showed no monotonically in-
creasing or decreasing trends, the behavior was
considered stable. Following stability on the
initial determination, the schedules were re-
versed on the keys. That is, the multiple sched-
ule replaced the mixed, and vice versa. The
pigeons were exposed to these terminal links
until they again satisfied the stability criterion.
Following stability of choice on the reversal,
the probability was changed, and the pigeons
began responding under the new condition,
first with 10 sessions of mixed vs. mixed sched-
ules, then with the initial and reversal of the
multiple vs. mixed schedules. Thus, the 10 ses-
sions of equal mixed vs. mixed schedules were
always interposed between determinations at
different probability levels. In addition, the
initial determination and the reversal were per-
formed on the same exposure to a given proba-
bility level. The order of probability levels was
quasi-random. Individual sessions were termi-
nated automatically after 80 reinforcements.
Sessions were conducted 6 days per week, with
the pigeons under approximately 23-hr food
deprivation. Table 1 presents the order of con-
ditions and the number of sessions for each
condition to which the pigeons were exposed.
The conditions of Experiment 2 were inter-
spersed between two of the present conditions,
as noted by an asterisk. (We decided to add
probability levels of .05 and .95 after learning
of Green and Rachlin's 1977 results. Hence,
these conditions were conducted after comple-
tion of Experiment 2).

RESULTS

The choice proportions, expressed in terms
of the multiple schedule, are shown in Fig-

Table 1

Order of conditions, number of sessions at each probability level, absolute rates of responding in responses per minute, and choice proportions, for each subject in Experiment I. Standard deviations appear in parentheses.

Pigeon	Order of conditions	Number of sessions	p *level of* FI-10-sec outcome	Terminal links		Absolute rates of responding		Choice proportion (multiple or in mix-mix, left key)
				Left	Right	Left	Right	
B-20	1	10	.50	mix	mix	26	47	.36
		16	.50	mult	mix	53(4)	27(6)	.66(.05)
		15	.50	mix	mult	13(1)	84(9)	.86(.01)
	2	10	.85	mix	mix	30	32	.48
		16	.85	mult	mix	41(4)	36(4)	.53(.04)
		16	.85	mix	mult	33(2)	52(5)	.61(.03)
	3	10	.15	mix	mix	29	46	.39
		34	.15	mult	mix	50(5)	17(5)	.74(.05)
		25	.15	mix	mult	25(8)	48(11)	.66(.05)
	4	10	.65	mix	mix	30	44	.41
		15	.65	mult	mix	42(4)	26(2)	.62(.04)
		15	.65	mix	mult	27(2)	59(6)	.68(.02)
	5	10	.35	mix	mix	31	50	.38
		27	.35	mult	mix	41(2)	23(3)	.64(.02)
		20	.35	mix	mult	19(2)	67(12)	.78(.05)
	*6	10	.05	mix	mix	21	26	.45
		15	.05	mult	mix	18(6)	19(4)	.48(.04)
		18	.05	mix	mult	23(5)	20(3)	.46(.03)
	7	10	.95	mix	mix	24	34	.41
		16	.95	mult	mix	22(4)	21(1)	.51(.04)
		20	.95	mix	mult	21(3)	37(5)	.64(.04)
B-22	1	10	.50	mix	mix	23	26	.46
		17	.50	mult	mix	36(8)	26(6)	.58(.03)
		21	.50	mix	mult	16(4)	47(4)	.74(.06)
	2	10	.85	mix	mix	11	32	.26
		20	.85	mult	mix	26(4)	29(3)	.47(.05)
		18	.85	mix	mult	22(2)	35(6)	.62(.02)
	3	10	.15	mix	mix	31	36	.46
		29	.15	mult	mix	48(7)	10(3)	.83(.05)
		30	.15	mix	mult	20(6)	52(7)	.72(.06)
	4	10	.65	mix	mix	23	33	.47
		25	.65	mult	mix	33(1)	34(3)	.48(.03)
		16	.65	mix	mult	25(3)	50(7)	.66(.04)
	5	10	.35	mix	mix	33	48	.40
		15	.35	mult	mix	44(4)	21(3)	.68(.03)
		18	.35	mix	mult	16(4)	51(6)	.77(.05)
	*6	10	.05	mix	mix	7	13	.35
		15	.05	mult	mix	13(8)	8(6)	.62(.04)
		17	.05	mix	mult	9(2)	29(4)	.75(.05)
	7	10	.95	mix	mix	11	37	.23
		22	.95	mult	mix	20(2)	20(2)	.49(.04)
		15	.95	mix	mult	15(2)	35(4)	.70(.04)
2958	1	10	.50	mix	mix	53	43	.55
		21	.50	mult	mix	81(6)	22(4)	.78(.05)
		15	.50	mix	mult	16(8)	69(4)	.82(.07)
	2	10	.85	mix	mix	31	23	.57
		15	.85	mult	mix	49(12)	38(13)	.55(.06)
		15	.85	mix	mult	20(9)	37(21)	.65(.09)

Table 1 *continued*

Pigeon	Order of conditions	Number of sessions	p *level of FI-10-sec outcome*	Terminal links Left	Terminal links Right	Absolute rates of responding Left	Absolute rates of responding Right	Choice proportion (multiple or in mix-mix, left key)
	3	10	.15	mix	mix	44	53	.45
		34	.15	mult	mix	60(26)	17(11)	.78(.06)
		24	.15	mix	mult	6(4)	78(17)	.93(.04)
	4	10	.65	mix	mix	32	31	.51
		19	.65	mult	mix	49(9)	24(5)	.67(.07)
		27	.65	mix	mult	30(5)	53(17)	.64(.02)
	5	10	.35	mix	mix	27	63	.30
		15	.35	mult	mix	82(17)	22(5)	.79(.06)
		15	.35	mix	mult	20(5)	76(8)	.79(.05)
	*6	10	.05	mix	mix	7	17	.29
		15	.05	mult	mix	49(16)	14(8)	.78(.05)
		16	.05	mix	mult	9(8)	45(18)	.83(.06)
	7	10	.95	mix	mix	30	28	.51
		24	.95	mult	mix	29(7)	27(7)	.52(.02)
		15	.95	mix	mult	23(3)	31(6)	.57(.02)
6242	1	10	.50	mix	mix	17	16	.52
		15	.50	mult	mix	18(3)	20(3)	.48(.03)
		16	.50	mix	mult	28(9)	28(4)	.50(.04)
	2	10	.15	mix	mix	8	11	.43
		26	.15	mult	mix	29(6)	29(7)	.50(.05)
		15	.15	mix	mult	35(5)	36(7)	.51(.02)
	3	10	.85	mix	mix	25	25	.50
		16	.85	mult	mix	25(4)	19(5)	.57(.02)
		15	.85	mix	mult	26(3)	20(5)	.43(.02)
	4	10	.35	mix	mix	24	20	.55
		51	.35	mult	mix	29(7)	46(9)	.39(.04)
		17	.35	mix	mult	38(6)	55(8)	.59(.07)

*Experiment 2 conditions conducted at this point.

ure 1. Table 1 shows the absolute response rates on which these proportions are based. In all cases, data are averaged over the last nine sessions on a procedure, i.e., the sessions satisfy the stability criterion. The standard deviations of both the choice proportions and the absolute response rates are shown in parentheses. In addition, the table presents mean choice proportions and absolute response rates for the final 3 (of the 10) sessions in which mixed schedules were associated with each terminal link, for each condition. Note that one bird, Pigeon 6242, failed to show systematic preference for the multiple schedule, an outcome inconsistent with those of the other subjects in this and prior studies. As Figure 1 shows, each of the subjects which showed a reliable preference for the multiple schedule displayed an inverted U-shaped function, which turned down at different places, for different subjects. With respect to the primary question of this study, the data of Pigeons B-22, B-20, and 2958 show that choice proportions tended to decrease as the likelihood of positive outcome increased. This finding may be seen more clearly in Table 2, which groups complementary choice proportions for each of the three subjects showing preference for the multiple schedule averaged across the two exposures to each condition. The numbers in parentheses (under the Δ symbols) are the choice proportions when the lower valued outcome is less probable minus the choice proportion when the lower valued outcome is more probable. In eight of nine cases, this number is positive (mean difference of +.14).

DISCUSSION

A puzzling aspect of the present data is one pigeon's failure to prefer the multiple schedule. We have no explanation for this anomaly. Since preference for multiple over mixed schedules is well established, however, and since the purpose of the present study was to evaluate
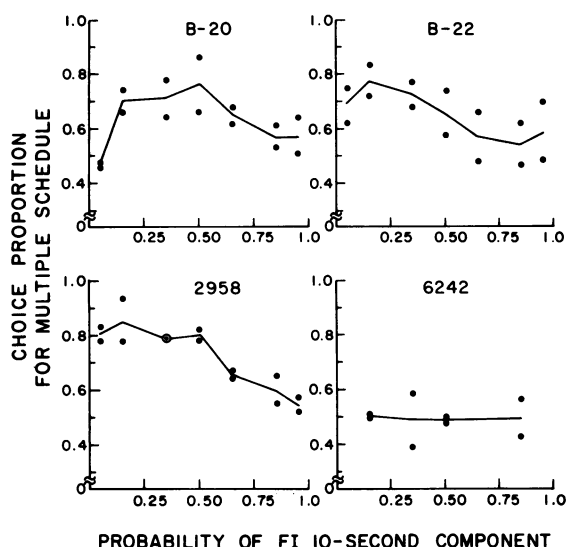
PROBABILITY OF FI 10-SECOND COMPONENT

Fig. 1. Choice proportion for the multiple schedule as a function of the probability that the component in the terminal link is FI 10-seconds (rather than FI 60-seconds). Data are from Experiment 1 and are presented for each of the four subjects. The solid line represents the mean of the choice proportions (filled circles) obtained on the first exposure to and on the position reversal at a given probability value.

how such preference varied as a function of the probability of the higher and lower valued outcomes, this pigeon's data may be dismissed from further consideration.

The results from the three pigeons that did show preference for the multiple schedule are consistent with those of Eckerman (1973) and with the literature on observing (Fantino, 1977): the strength of a stimulus in a choice situation as well as in an observing-response test is consistent with the delay-reduction hypothesis but inconsistent with the uncertainty-reduction hypothesis.

The present results, of course, are quite inconsistent with those found by Green and Rachlin (1977). Whereas 8 of 9 comparisons

in the present study support an asymmetry in which preference is greater for the multiple schedule when the positive outcome is less likely (Table 2), 17 of 20 comparisons in Green and Rachlin's study support the opposite asymmetry (their Figure 2, mean function panel). The mean difference averaging over the nine comparisons in our study is 14%, in theirs 4%, but in the opposite direction (estimate from their Figure 2). It is possible that the difference between their results, on the one hand, and ours and Eckerman's (1973), on the other, is due to their use of extinction and blackout as the lesser valued outcome. If one views extinction as an end point on a rate of reinforcement continuum, one may well ask what results would obtain if a much lower-valued schedule than FI 60-sec were employed with the present procedure. It is possible, for example, that with a sufficiently long FI as the lesser valued outcome results would have been more comparable to those of Green and Rachlin. Alternatively, Green and Rachlin's results may depend on properties uniquely associated with extinction and/or blackout.

In any case, the present results, using a conventional concurrent-chains procedure, are consistent with those from the observing response literature: pigeons prefer multiple schedules to comparable mixed schedules and tend to show greater preferences when the probability of the more positive outcome is below .50 than at complementary points.

EXPERIMENT 2

Prior comparisons of mixed and multiple schedules have. presented no more than a single reinforcement during each exposure to a terminal link. In the present study, however, two reinforcements were available in each terminal link, one on an FI 60-sec schedule, the

Table 2

Mean choice proportion for each of three subjects at each of three complementary pairs of points. The difference between each pair of points (Δ) and the means of these differences are also shown.

Pigeon	Conditions						Mean Δ
	.95 vs. .05	*(Δ)*	*.85 vs. .15*	*(Δ)*	*.65 vs. .35*	*(Δ)*	
B-20	.58 vs. .47	(−.11)	.57 vs. .70	(+.13)	.65 vs. .71	(+.06)	+.03
B-22	.60 vs. .68	(+.08)	.54 vs. .78	(+.24)	.57 vs. .72	(+.15)	+.16
2958	.54 vs. .80	(+.26)	.60 vs. .86	(+.26)	.66 vs. .79	(+.13)	+.22
Mean Δ		+.08		+.21		+.11	+.14

other on an FI 10-sec schedule. Which schedule was in effect first was determined probabilistically. As in the first experiment, conditions were identical on the two keys except that one terminal-link schedule was multiple and the other mixed. One question of interest is whether or not subjects will prefer multiple to mixed schedules as they do when only a single reinforcement occurs during each terminal link. Moreover, if preference does occur for the multiple schedule, will it vary as a function of the probability that the first reinforcement is the positive outcome?

METHOD

Subjects and Apparatus

Same as in Experiment 1.

Procedure

The initial links were the same as in Experiment 1. In Experiment 2, the pigeon produced both the FI 60-sec and FI 10-sec schedules in a given exposure to a terminal link; a probability gate randomly selected the schedule that was to be first in the sequence of two. The remaining schedule followed reinforcement provided by the first. Thus, on some terminal-link entries, the pigeon produced an FI 60-sec schedule followed by an FI 10-sec schedule, and on others the pigeon produced an FI 10-sec schedule followed by an FI 60-sec schedule. The initial links were reinstated after the second reinforcement in a terminal link. As in Experiment 1, there were 10 sessions in which both terminal-link schedules were mixed schedules at each probability level. Comparisons were then made in which one terminal link was associated with a mixed schedule and the other with a multiple schedule. The key colors were the same as in Experiment 1.

The data of primary interest are the choice proportions as a function of the following five different probabilities that the FI 10-sec FI 60-sec sequence of schedules would be produced given a terminal-link entry: .00, .25, .50, .75, and 1.00. For example, at the probability level designated 1.00, the pigeon always produced an FI 10-sec FI 60-sec sequence in either terminal link. At the .75 probability level, the pigeon produced an FI 10-sec FI 60-sec sequence on approximately 75% of the terminal-link entries; on the remaining 25%, it produced an FI 60-sec FI 10-sec sequence.

Individual sessions were terminated after 60 reinforcements. Other details were the same as in Experiment 1. Table 3 presents the order of conditions and the number of sessions for each condition to which the pigeons were exposed.

RESULTS

The choice proportions are presented in Figure 2 for the multiple schedule as a function of the probability that the FI 10-sec schedule would be produced first in the sequence of two schedules. Table 3 presents the absolute response rates on which these choice proportions are based. In all cases, data are averaged over the last nine sessions on a procedure, i.e., the sessions satisfying the stability criterion. The standard deviations of both the choice proportions and the absolute response rates are shown in parentheses. In addition, the table presents mean choice proportions and absolute response rates for the final 3 (of the 10) sessions in which mixed schedules were associated with each terminal link, for each condition. As in Experiment 1, Pigeons B-22, B-20, and 2958 tended to prefer the multiple over the mixed schedule at the various probability levels. A trend for the preferences to decrease
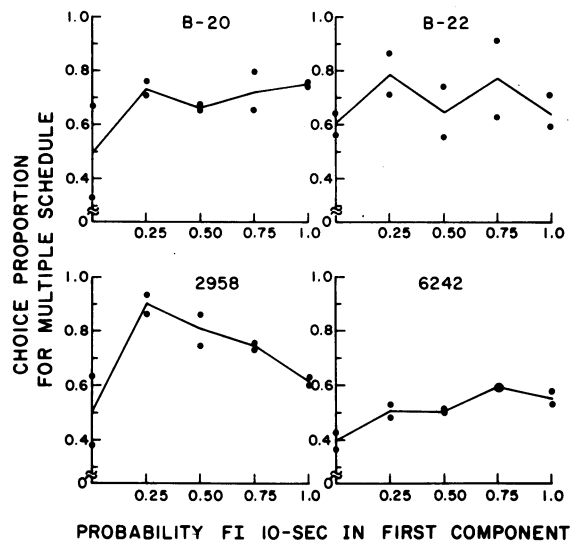

Fig. 2. Choice proportion for the multiple schedule as a function of the probability that the first component in the terminal link is FI 10-seconds. Data are from Experiment 2 and are shown for each of the four subjects. The solid line represents the mean of the choice proportions (filled circles) obtained on the first exposure to and on the position reversal at a given probability value.

Table 3

Order of conditions, number of sessions at each probability level, absolute rates of responding in responses per minute, and choice proportions, for each subject in Experiment 2. Standard deviations appear in parentheses.

Pigeon	Order of conditions	Number of sessions	p level of FI-10-sec outcome	Terminal links		Absolute rates of responding		Choice proportion (multiple or in mix-mix, left key)
				Left	Right	Left	Right	
B-20	1	10	1.00	mix	mix	33	48	.41
		21	1.00	mult	mix	55(5)	18(5)	.75(.05)
		15	1.00	mix	mult	25(4)	74(4)	.74(.03)
	2	10	.00	mix	mix	15	15	.50
		21	.00	mult	mix	7(3)	14(7)	.33(.09)
		39	.00	mix	mult	13(5)	26(9)	.67(.04)
	3	10	.50	mix	mix	37	45	.45
		34	.50	mult	mix	58(6)	30(2)	.65(.03)
		15	.50	mix	mult	33(5)	66(10)	.67(.06)
	4	10	.25	mix	mix	32	35	.48
		19	.25	mult	mix	47(19)	15(8)	.76(.06)
		15	.25	mix	mult	26(4)	63(6)	.71(.04)
	5	10	.75	mix	mix	18	22	.45
		15	.75	mult	mix	28(3)	15(6)	.65(.07)
		15	.75	mix	mult	16(4)	59(15)	.79(.03)
B-22	1	10	.00	mix	mix	7	14	.33
		15	.00	mix	mult	6(4)	8(4)	.56(.06)
		24	.00	mult	mix	5(2)	3(1)	.64(.04)
	2	10	1.00	mix	mix	18	20	.47
		26	1.00	mult	mix	37(3)	25(3)	.59(.04)
		22	1.00	mix	mult	17(6)	42(16)	.71(.02)
	3	10	.50	mix	mix	27	35	.44
		20	.50	mult	mix	33(13)	26(11)	.55(.04)
		15	.50	mix	mult	15(6)	43(9)	.74(.05)
	4	10	.25	mix	mix	10	10	.50
		17	.25	mult	mix	47(8)	8(4)	.86(.07)
		15	.25	mix	mult	20(2)	46(18)	.71(.04)
	5	10	.75	mix	mix	26	21	.55
		15	.75	mult	mix	32(3)	18(2)	.63(.04)
		15	.75	mix	mult	6(2)	61(18)	.91(.03)
2858	1	10	.00	mix	mix	24	45	.35
		15	.00	mult	mix	11(10)	18(11)	.38(.05)
		16	.00	mix	mult	5(4)	8(5)	.63(.04)
	2	10	1.00	mix	mix	8	21	.28
		19	1.00	mult	mix	37(7)	22(9)	.63(.06)
		21	1.00	mix	mult	33(7)	49(17)	.60(.05)
	3	10	.50	mix	mix	27	34	.44
		16	.50	mult	mix	37(19)	13(6)	.74(.07)
		25	.50	mix	mult	5(4)	30(15)	.86(.07)
	4	10	.75	mix	mix	35	43	.44
		16	.75	mult	mix	57(8)	22(5)	.73(.06)
		17	.75	mix	mult	20(6)	60(7)	.75(.06)
	5	10	.25	mix	mix	24	35	.41
		15	.25	mult	mix	67(18)	11(3)	.86(.05)
		15	.25	mix	mult	6(5)	66(24)	.93(.05)
6242	1	10	.00	mix	mix	13	17	.43
		15	.00	mult	mix	11(5)	19(10)	.36(.06)
		24	.00	mix	mult	11(5)	8(4)	.42(.04)

Table 2 *continued*

Pigeon	Order of conditions	Number of sessions	p level of FI-10-sec outcome	Terminal links		Absolute rates of responding		Choice proportion (multiple or in mix-mix, left key)
				Left	Right	Left	Right	
	2	10	1.00	mix	mix	30	22	.58
		19	1.00	mix	mult	26(5)	35(4)	.58(.04)
		19	1.00	mult	mix	17(7)	15	.53(.04)
	3	10	.50	mix	mix	26	26	.50
		15	.50	mult	mix	28(4)	28(5)	.50(.04)
		25	.50	mix	mult	53(7)	54(9)	.51(.07)
	4	10	.75	mix	mix	38	33	.54
		15	.75	mult	mix	43(4)	30(3)	.59(.02)
		19	.75	mix	mult	33(5)	46(3)	.59(.03)
	5	10	.25	mix	mix	18	21	.46
		17	.25	mult	mix	17(7)	18(9)	.48(.08)
		15	.25	mix	mult	12(4)	14(5)	.53(.04)

with successive increases in the probability level that the FI 10-sec schedule would occur first, i.e., a pattern similar to that found in Experiment 1, was apparent only for Pigeon 2958. Also, as in Experiment 1, Pigeon 6242 failed to show a consistent preference for the multiple schedule. If the data from the one complementary pair of points ($p = .25$ and $.75$) were arranged as in Table 2 for the three pigeons showing a multiple schedule preference, they would reveal that all three showed the same direction of asymmetry as they did in Experiment 1, with a mean difference of $+.6$. Inspection of the individual data, however, shows that this asymmetry is demonstrated convincingly only for Pigeon 2958.

DISCUSSION

The same pigeons that preferred multiple to mixed schedules in Experiment 1 did so when two reinforcements were arranged in each terminal link in Experiment 2. Two of the three pigeons, however, showed no systematic change in preference as a function of the probability that the shorter schedule occurred first. The third pigeon (2958) showed the same asymmetrical pattern as in the first experiment, a pattern also consistent with Eckerman's (1973) results on sequential choice and that found in the observing literature (cf. Fantino, 1977).

According to the delay-reaction hypothesis, preference should be highest for the multiple schedule when $p = .25$, intermediate when $p = .50$, and lowest but still above indifference when $p = .75$ (again, probabilities are ex-

pressed in terms of the shorter schedule occurring first; thus, preference should decrease with higher p values). According to the uncertainty-reduction hypothesis, however, preference should be highest when $p = .50$. The delay-reduction hypothesis was only partially supported by the results from these three conditions. In support of the hypothesis, the highest preference occurred at $p = .25$ for each of the three pigeons preferring the multiple schedule. On the other hand, preference at $p = .50$ was lower than that at $p = .75$ for two of the three birds, a result inconsistent with the hypothesis. The uncertainty-reduction hypothesis fared much more poorly in accounting for preference in these three conditions: the lowest mean preference occurred at the predicted maximum ($p = .50$) for all but one pigeon (2958). Thus, the pattern of results in this second experiment failed to support conclusively either hypothesis but is especially uncongenial for the uncertainty-reduction view.

GENERAL DISCUSSION

The first of the present experiments supports the delay-reduction hypothesis, successfully extending principles from the observing-response literature to choice as measured with a standard concurrent-chains procedure. Results from the second experiment extend preference for multiple over mixed schedules to a modified concurrent-chains procedure. Here, however, support for the delay-reduction hypothesis was only suggestive. In both experiments, the uncertainty-reduction hypothesis

failed to account for much of the relevant data. Thus, the results from these experiments are consistent with those from the observing-response literature in suggesting that the strength of a stimulus cannot be well described as a function of the degree of uncertainty reduction the stimulus provides about reinforcement.

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